STREAM GRADIENT CHANGES OF DRY CREEK

AS INDICATED BY FLOODPLAIN GRADIENTS

by

Michael S. Raimonde

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Garry D. McKenzie

Advisor

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Abstract

Dry Creek is a gravel bed stream that has undergone a shift from equilibrium. The result has been degradation that has eroded over two acres from the "Big Bend" on the Finney Farm near Newark in Licking County, Ohio. There are three factors that may cause upstream degradation, the lowering of the base level, a decrease in the river length, or the removal of a control point. All of these result in an increase in the local slope and result from excavation of bed material, lowering of the main river level, the cutoff of a meander, or the removal of a dam. At Dry Creek at least three modifications to the natural flow of the stream has occurred, excavation of bed material by a sand and gravel company, a meander cutoff downstream from the "Big Bend", and bank armouring upstream. The production of floodplain terraces and documentation of their gradients suggest an increase in the local slope of the stream since the start of gravel excavation.

Introduction

Subject and Purpose. The purpose of this project was to determine floodplain gradients, and to document their changes with time on Dry Creek in Licking County, Ohio. The focus of the study was the "Big Bend" on the Finney Farm, where rapid changes in stream morphology are occurring. Finally, this study should serve as a basis for further investigations to determine the mechanisms and rates of change in the stream, and to explain their causes.

Historical Background. Dry Creek is a third order, ephemeral, gravel bed stream located 6.4 kilometers north of Newark in Licking County, Ohio (Figure 1,2, and 3). Progressive upstream degradation has eroded over two acres of land around the "Big Bend" on the Finney Farm (Figure 4) and has formed floodplain terraces on the acre~~a~~ting point-bar (Figure 5). A study of aerial photographs indicates that degradation has progressed upstream since the start of sand and gravel mining in 1945 and rapid migration of the "Big Bend", 2 kilometers from the mouth of the stream, has occurred since the early 1960's.

At least three modifications have been made to the natural flow of the stream. Excavation in the bed of the stream by the Dry Creek Sand and Gravel Company, 1.2 kilometers from the mouth of the stream, has continued since 1945. Upstream from the gravel excavation, 1.7 kilometers from the mouth of the stream, the stream was shortened in order to protect a dwelling. More recently, an attempt has been made to armour the bank upstream from the "Big Bend" (Figure 6). As might

Figure 1. Map of Ohio indicating location of Licking County.

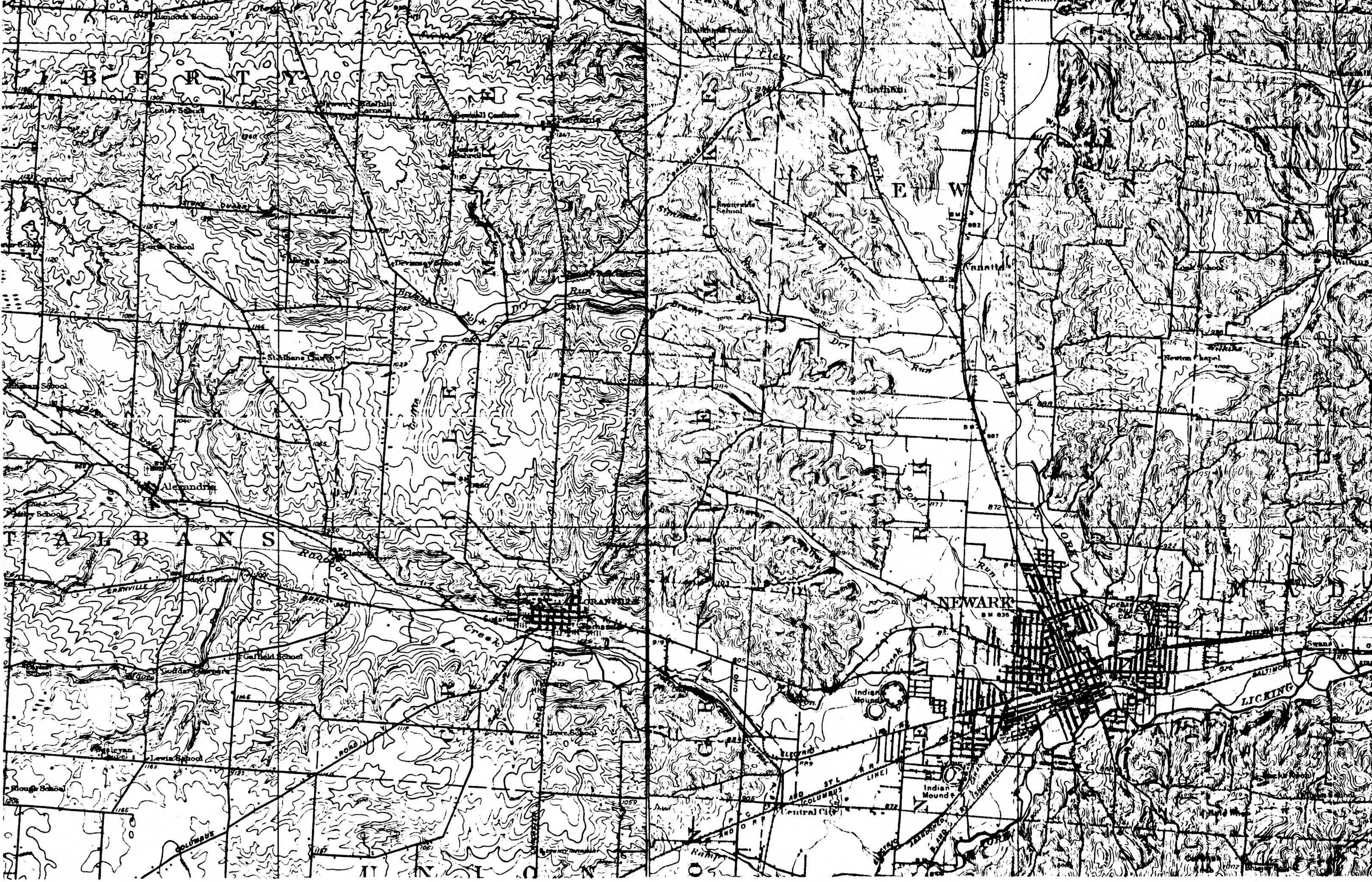


Figure 2. Fifteen-minute contour map (reduced 0.65 X) showing the location of Dry Creek, 6.4 Km north of Newark. (Herron,1910; Sutton,1910)

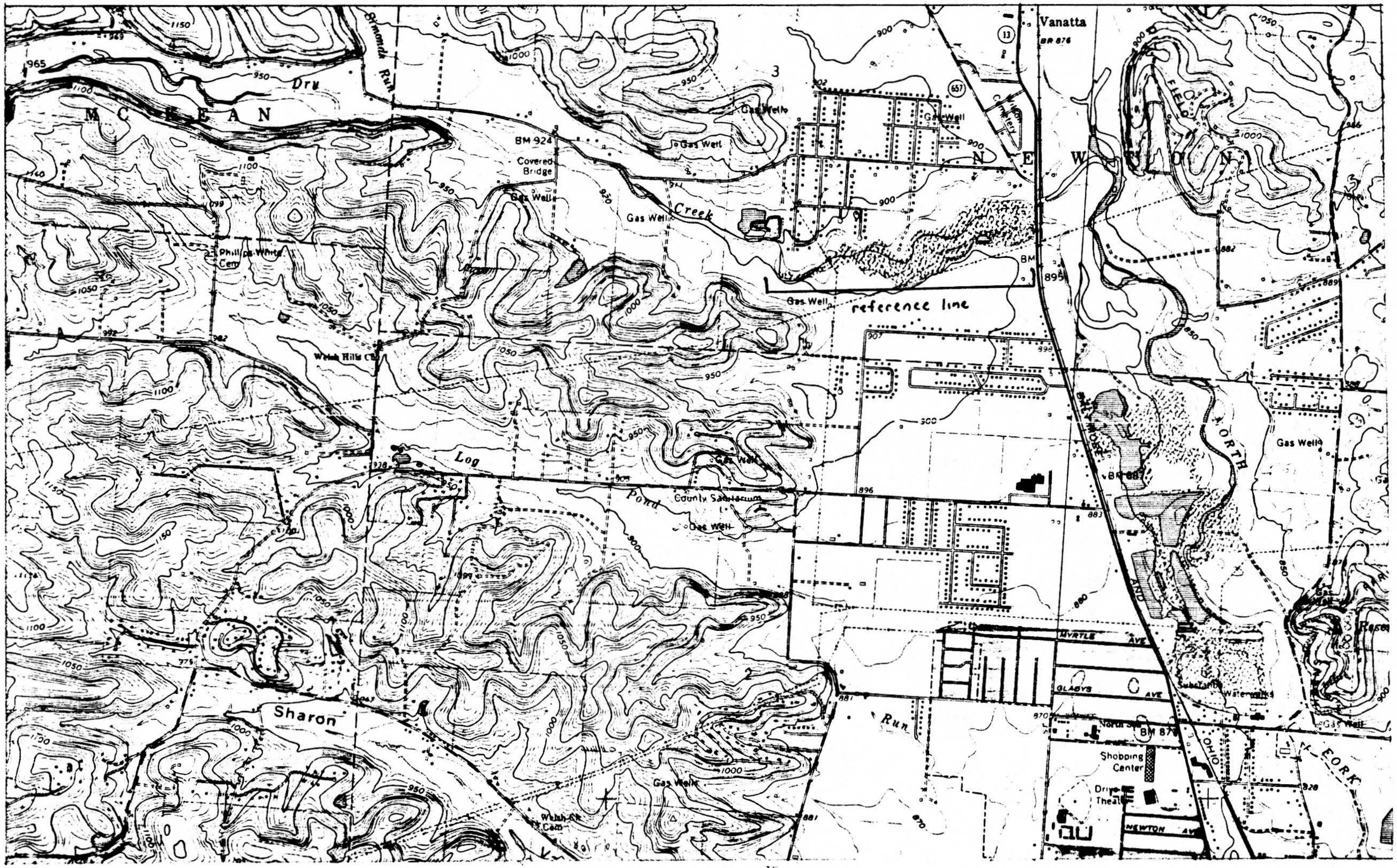


Figure 3. Seven and one-half-minute contour map showing location of Dry Creek. The reference line indicates location of the study reach. (U.S. Geologic Survey, 1982)

a.

b.

c.

Figure 4. Progressive degradation on the "Big Bend". a. View south-east from western part of bend. b. View east from south edge of the bend. c. View to south of drainage cut. Jacob's staff is 5 feet tall.

Figure 5. Point Bar of the "Big Bend". View is northerly from the south side of the bend. Arrows indicate flood-plain-scarps that were examined in this study.

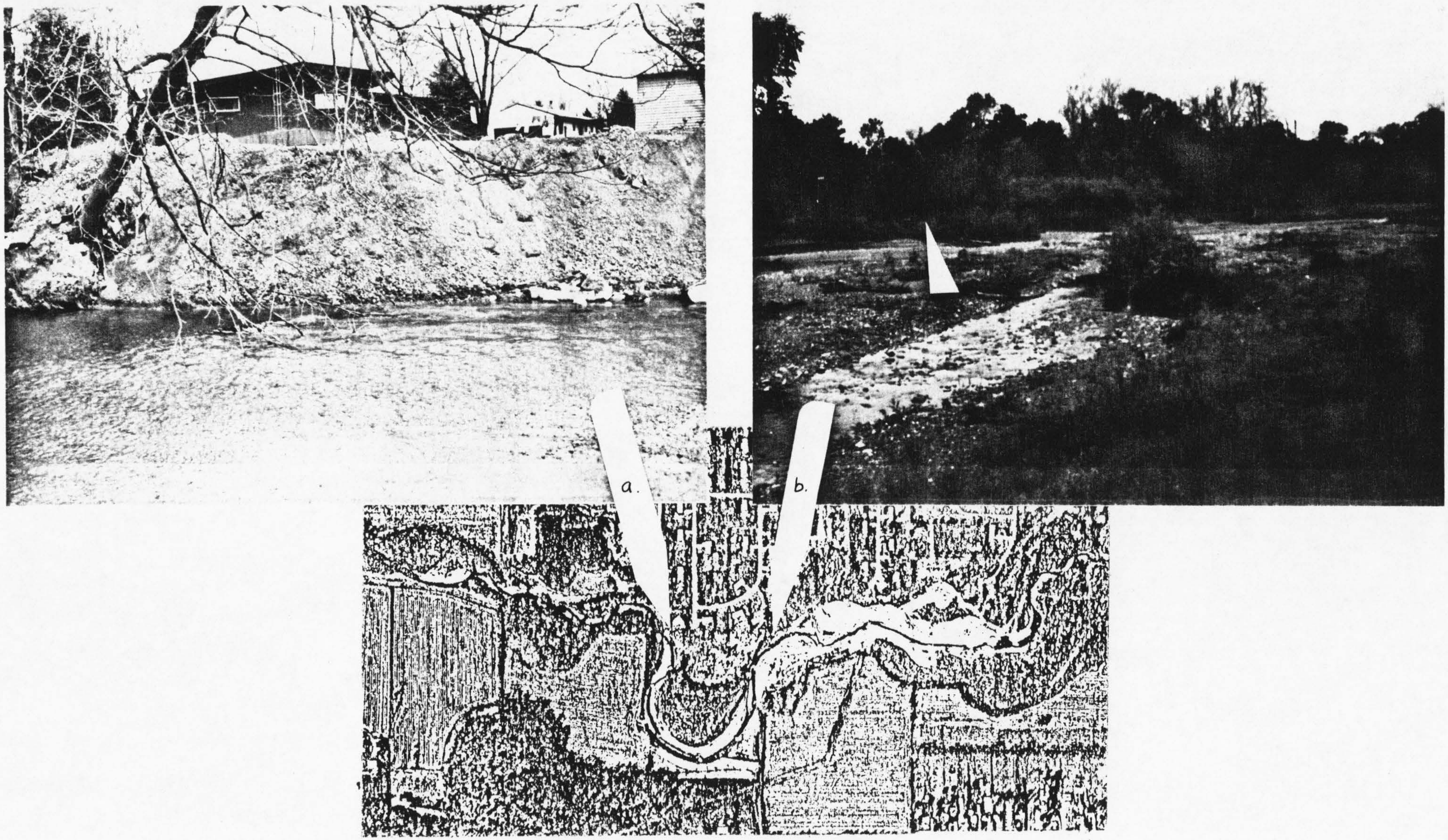


Figure 6. Location of stream cutoff and bank armouring. a. Resident attempting to armour the bank from further erosion. b. Stream cutoff shortened the stream 1444 feet.

be expected from such modifications, the stream has migrated and resulted in degradation.

Scope and Limitations. This study determines the floodplain gradients on the "Big Bend" and documents their changes. It compares these gradients to the gradient of the rest of the stream. The recent rates of change are determined and a comparison with the valley is made. Finally, it speculates on the causes of the recent shift from equilibrium.

Because the control features (dwellings, fences, and powerlines) and spot elevations are misaligned with the contours on the available base map, floodplain-gradients were determined with field measure-ments and the floodplain-scarps may not correspond with the spot ele-vations on the base map.

Literature Review

Streams tend to move toward equilibrium (Hickey,1969) by the mutual adjustments of the components of the drainage basin. In order to maintain transportation of water and sediment, adjustments occur in slope, river channels, and structure of the drainage basin (Richards, 1982). When an external stress is applied to a stream, the variables will adjust until equilibrium is again restored. Here, equilibrium is on the order of ten's of years.

Variables. Streams are free to adjust their velocity, hydraulic radius, slope, wetted perimeter, maximum depth of flow, sinuosity, and their meander arc length by erosion and deposition. These stream adjustments take place in response to changes in discharge, sediment size, bank material and the slope of the valley (Hey, 1982). The processes that govern these responses include flow resistance, sediment transport, bank erosion, bar deposition, and meandering. Each of these processes require equations defined by the above variables, but many of these equations are not well defined. Figure 7 displays both on- and off-site factors that influence the drainage basin. With the change of one of these variables, another is immediately affected. Therefore, it is often difficult to determine the original cause (Hey, 1982).

Causes of Degradation. The three causes of upstream degradation directly relate to an increase in the slope of the stream (Galay, 1983). An increase in slope results when the base level has been lowered by a drop in lake level, drop in the main river level, or by excavation of bed material. A decrease in the river's length by a cutoff, channelization, or a horizontal shift of the base level will also result in an increase in slope. When a control point that maintained the slope, such as a dam, is removed, the result is also an increase in the stream's slope (Figure 8). Geologic factors may also affect slope such as climatic changes, which may include isostatic rebound from glaciation, and tectonics (Richards, 1982).

The amount and size of the bed material that a stream will carry and water discharge are all related to the slope. This relationship is depicted by

$$S \propto \frac{Q_s^a D^b}{Q^c} \quad .$$

Influences of site and non-site factors

Independent and influencing variables \ Dependent variables	Soils	Landslides	Vegetation	Topography	Sediment yield	Runoff	Channel widening	Channel deepening	Sinuosity changes	Flow	Channel width	Channel depth	Channel slope	Bank materials	Sediment discharge	Flows (Basin)	Bank erosion
Flow							X	X	X		$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$		
Topography	X	X	X			X										X	
Sediment discharge							X	X	X		$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$			
Soils		X	X		X	X											
Climate*	X		X	X		X											
Bank materials							X	X	X	$\boxed{X}$							
Lithology*	X	X		X													
Flows (basin)		X			X					X							
Landslides	X			X	X												
Vegetation	X				X	X											
Runoff		X			X											X	
Forestry*	X		X														
Roads*			X	X													
Structure/tectonics*		X		X													
Grazing*			X														
Channel width										$\boxed{X}$							
Channel depth										$\boxed{X}$							
Channel slope										$\boxed{X}$							
Channel widening																	X
Channel deepening																	X
Sinuosity changes																	X
Sediment yields															$\boxed{X}$		

* Independent variables.
Flow Site factors.
X Link between variables.
X Links between site and non-site factors.

Figure 7. Influences of site and non-site factors. (Patrick, 1982)

Causes of River Bed Degradation

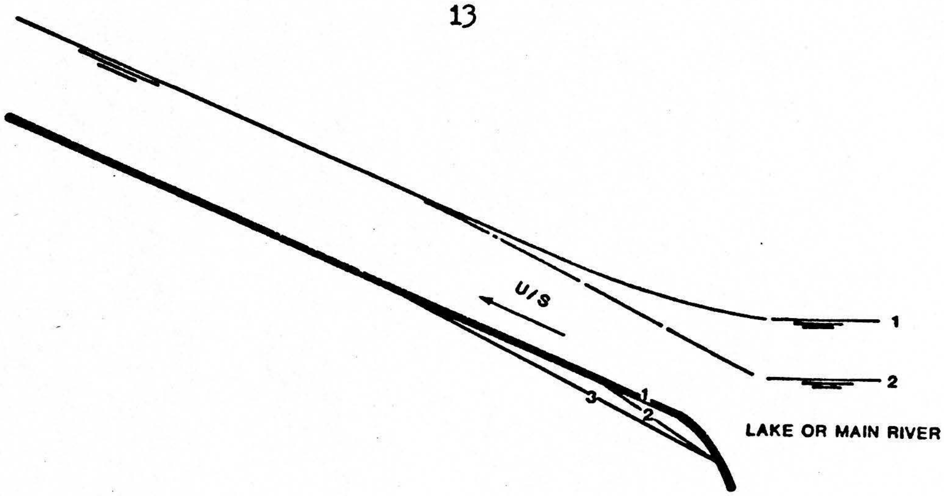
Type of Degradation	Primary Cause	Type of River Change or Engineering Works to Cause Degradation
1. Downstream progressing (*D/S*) →	decrease of bed material discharge, $Q_s \downarrow$	(1) construction of high dam (2) construction of low dam (3) excavation of bed material (4) diversion of bed material (5) change in land use (6) storage of bed material
	increase water discharge, $Q \uparrow$	(1) diversion of flow (2) rare floods
	decrease in bed material size, $D \downarrow$	(1) river processes
	other	(1) river emerging from lake (2) thawing of subsurface permafrost
2. Upstream progressing (*U/S*) ←	lower base level	(1) drop in lake level (2) drop in level of main river (3) excavation of bed material
	decrease river length	(1) cutoff (2) channelization and regulation (3) horizontal shift of base level (4) stream capture
	removal of control point	(1) natural erosion (2) removal of dam

Figure 8. Causes of River Bed Degradation. Progressing upstream degradation is caused by an increase in slope. (Galay, 1983)

This relationship suggests that slope (S) is proportional to bed sediment discharge (Q_s) and bed material size (D), and inversely proportional to water discharge (Q). Therefore, when slope is increased the stream is capable of increasing the discharge of sediment and the maximum size of particles. This would permit transportation (erosion) of particles that previously could not be transported. So, particles that previously armoured the streambed would now be transported causing upstream degradation until equilibrium is attained by the coarsening of the bed material and/or a change in the river pattern (Figure 9 and 10). A change in the river pattern resulting in increasing the length would decrease the slope, a change opposite of that of a cutoff. Finney (1983) has documented an increase in the size of the bed fraction from 40 to 86 milimeters between 1962 and 1983 at Dry Creek. The lateral migration of the stream at the "Big Bend" since the early 1940's suggests a response to an imposed increase in slope.

Man's Influence on Slope. Changes in land use may affect the flow regime of water such as the amount of surface area made impervеous which may also increase rate of flow across the surface. These changes cause adjustments in the stream channels in order to handle the flow (Leopold, 1968). Excavation of bed material results in upstream degradation as well as downstream degradation. This practice essentially lowers the local base level and increases its slope (Galay, 1983).

A common practice in river engineering is river training which includes cutoffs. A cutoff is a flow diversion that stops water flow



Note :U/S SIGNIFIES UPSTREAM PROGRESSING DEGRADATION.

Figure 9. Imposed change in river slope. Upstream progressing degradation caused by lowering the base level (here illusrtated as lake level) (Galay, 1983).

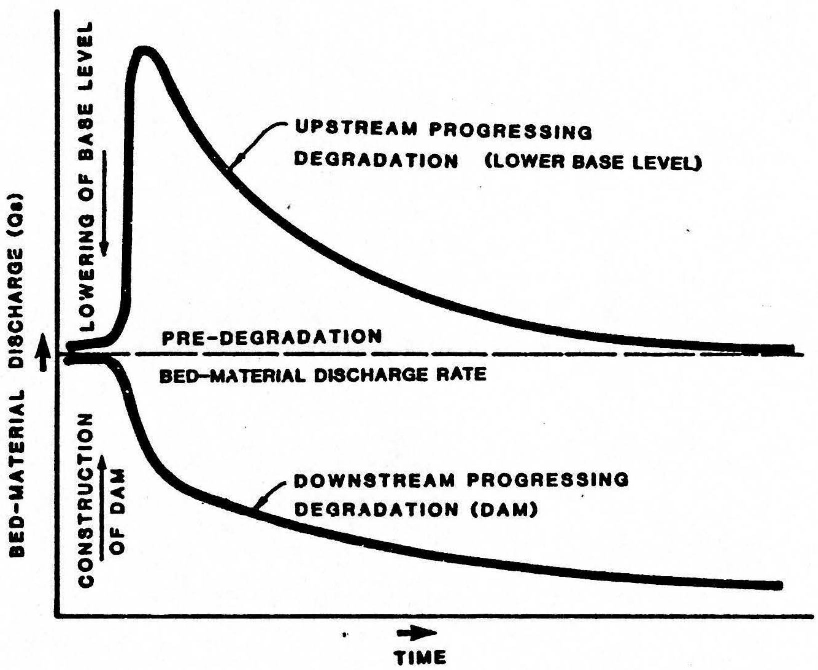


Figure 10. Changes of Bed Material Discharge during Degradation. Upstream progressing degradation will result in more bed material transported in a given time period compared to downstream degradation (Galay,1983).

into a meander which decreases the length of the stream. Associated with the decrease in channel length is local increase in slope and a decrease in roughness which results in an increase in velocity (Patrick, 1982) (Figure 11). This relationship is expressed in Manning's Equation,

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} ,$$

where velocity (V) is proportional to the slope (S) and the hydraulic radius (R) while inversely proportional to the coefficient of roughness (n). If slope was increased, Manning's Equation suggests the velocity would also increase. An increase in velocity would result in a lower coefficient of roughness, of which cobbles and gravel are about 0.03. As explained earlier, this increase in slope increases the competance of a stream to transport larger particles and more bed sediment. The result is local streambank erosion by channel entrenchment with removal of armouring material, bank failure due to the undercutting and oversteepening of the bank, and downstream erosion and aggradation. The effects of degradation, generally, will continue upstream until it reaches the headwaters (Patrick, 1982).

A variety of factors influence the rate and amount of which degradation occurs. Some important factors include the armouring of the streambed, the existence of cohesive material within the channel, the erosability of the stream's banks, and the existence of engineering works on the stream (Galay, 1983). In order to apply these succesfully, detailed equations must be designed.

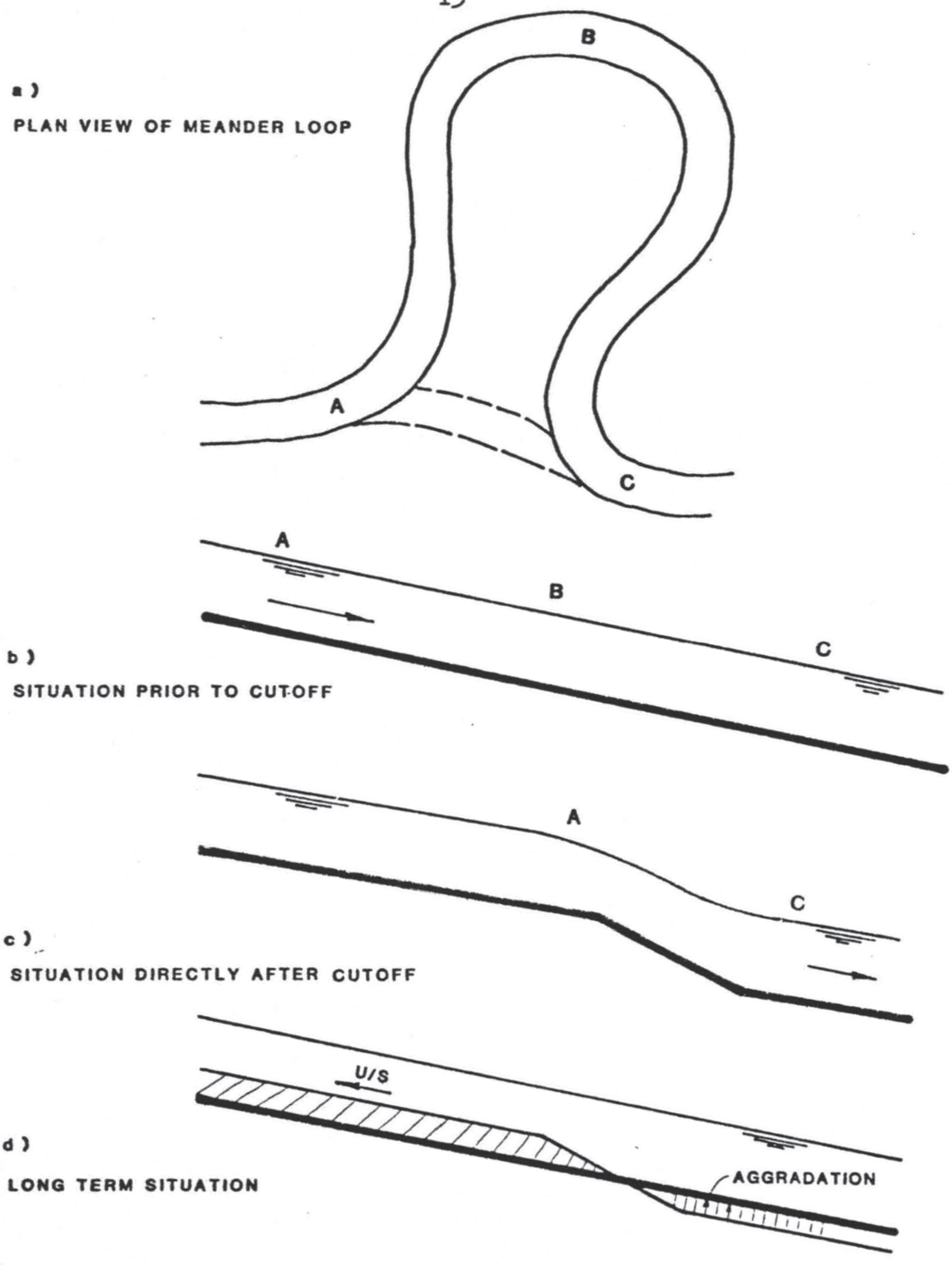


Figure 11. Upstream progressive degradation caused by a cutoff (Patrick, 1982).

Terraces. The formation of terraces along a stream reflects a relative base level change and/or variations in the discharge/ sediment yield ratios of the basin (Richards, 1982). When the base level is lowered, the stream channel incises into the alluvial material and bedrock of the valley floor. Bank erosion continues to widen the channel resulting in partial destruction of the terrace. This process may reoccur forming multiple terraces.

Surveying Equipment and Procedure

In order to map the floodplain terraces and determine their gradients, scarps chosen had to be somewhat laterally continuous and mappable to the scale of the base map. Five floodplains were chosen and their four scarps were mapped on the available base map.

Mapping of the floodplain scarps and determination of floodplain gradients was done with a plane table and alidade (Lahee, 1952). The base map was attached to the rectangular plane table with its compass directions corresponding to the edges of the plane table. After attaching the plane table to the tripod, it was centered over a reference point (Figure 12). Because the control features (dwellings, fences, and powerlines) were misaligned with the contours on the available base map, an initial reference point had to be established. This point was found by triangulating or taking bearings from various topographic features and determining their point of intersection which corresponded to the location that the plane table was stationed. The plane table was leveled by using the bubble level

Figure 12. Plane Table . The table is centered over a reference point and oriented to the compass directions. Surveying is done with the aid of an alidade (not shown), and the stadia rod seen in the distance.

attached to the base of the alidade. Orienting the edges of the plane table with the compass directions, and thus the attached base map, was accomplished by aligning the edges with the compass also attached to the base of the alidade.

From this reference point, the telescopic alidade was used to sight the location of the floodplain scarps. This was done by placing the stadia rod (held by the rodperson) at the location to be sighted. The stadia rod was aligned with the center line in the field of view of the alidade. The sighting distance was determined by counting the divisions of the stadia rod between the horizontal stadia cross-hairs in the alidade and multiplying by 100. In order to determine the elevation difference, the vertical angle was found by the Beaman Stadia Arc Method (Lahee, 1952). This method essentially uses a protractor attached to the alidade and a mark perpendicular to the table. Simple trigonometry and trigonometric tables were then employed to determine the map distance and elevation differences.

The interpretation of stream history through terrace development must consider several factors. The elevation of a terrace is not that of the stream at the time of deposition. Also, these terraces have lateral slopes perpendicular to the channel. Because there is possibly an unknown amount of post-depositional erosion of the flood-plain's surface, it may not represent the depositional level as it did when deposited. Additionally, longitudinal correlation of terraces must consider warping (Richards, 1982). Although surface erosion and warping are factors, they are not considered important here.

In order to handle high water discharge, streams often develop chute channels across the existing point bar. Because they tend to incise into the floodplain, they were avoided when determining gradients. The lateral slopes of the floodplains were alleviated by picking locations an equal distance from adjacent scarps, keeping the sighting distance to a minimum, and increasing the number of data points surveyed.

Because of the somewhat discontinuous nature of the scarps, their height was determined on the axis of the point bar. A hand level and Jacob's staff was used to determine the scarp heights and were considered to be average.

The base map, onto which the above information was plotted, was made by Henderson Aerial Survey from aerial photographs taken March 13, 1983. A scale of 1" equals 100' and a contour interval of 5' was used in contouring the map. Spot elevations provided on this map were not used to determine the floodplain gradients because the control features and spot elevations were misaligned to the contours and the scarps were mapped with respect to these contours. The original base map was traced for the production of a field map introducing minor error.

Examination of the whole stream's gradient was done with 1910 fifteen-minute topographic maps of the Newark and Granville quadrangles. These gradients were then compared to the floodplain gradients determined by the plane table method. In order to establish if other tributaries to the North Fork of the Licking River have similarly been affected, seven and one-half-minute quadrangles from 1961, 1970, 1974, and 1982 were examined. Aerial photographs dating back to 1930 were studied to determine ages of the floodplain terraces and to illustrate rapid upstream degradation.

The average rates of downcutting were determined by combining the ages of the floodplain and average scarp heights. Data collected and cross sections constructed by Finney (1983) were also used to examine rates of downcutting.

Results

With the imposed increase in slope, degradation is progressing upstream at Dry Creek. The resulting incision and bank erosion has formed five floodplain terraces (Figure 13 and 14). These terraces are separated by four scarps which were used as controls for age determination of the terraces. Aerial photographs were used to determine terrace ages by documenting the extent of lateral migration of the stream. Until the late 1940's, the oldest terrace,floodplain 5, was still active with a percent grade of 2.0 (Figure 15). Figure 16 shows degradation progressing upstream during development of floodplain 4 at 2.09 percent grade. Further incision (Figure 17) of the stream creates scarp 3 although channel widening destoyed much of the terrace (Figure 18 and 19). As the destruction occurred, floodplain 3 was developing at 2.15 percent grade and the cutbank was eroding. Floodplain 3 was abandoned in 1970 (Figure 20) by deeper incision and further migration. Floodplain 2 developed with a percent grade of 2.23 (Figure 21). Presently, the floodplain active on the "Big Bend" is floodplain 1 with a percent grade of 2.28 and it has been active since 1976 (Figure 22 and 23).

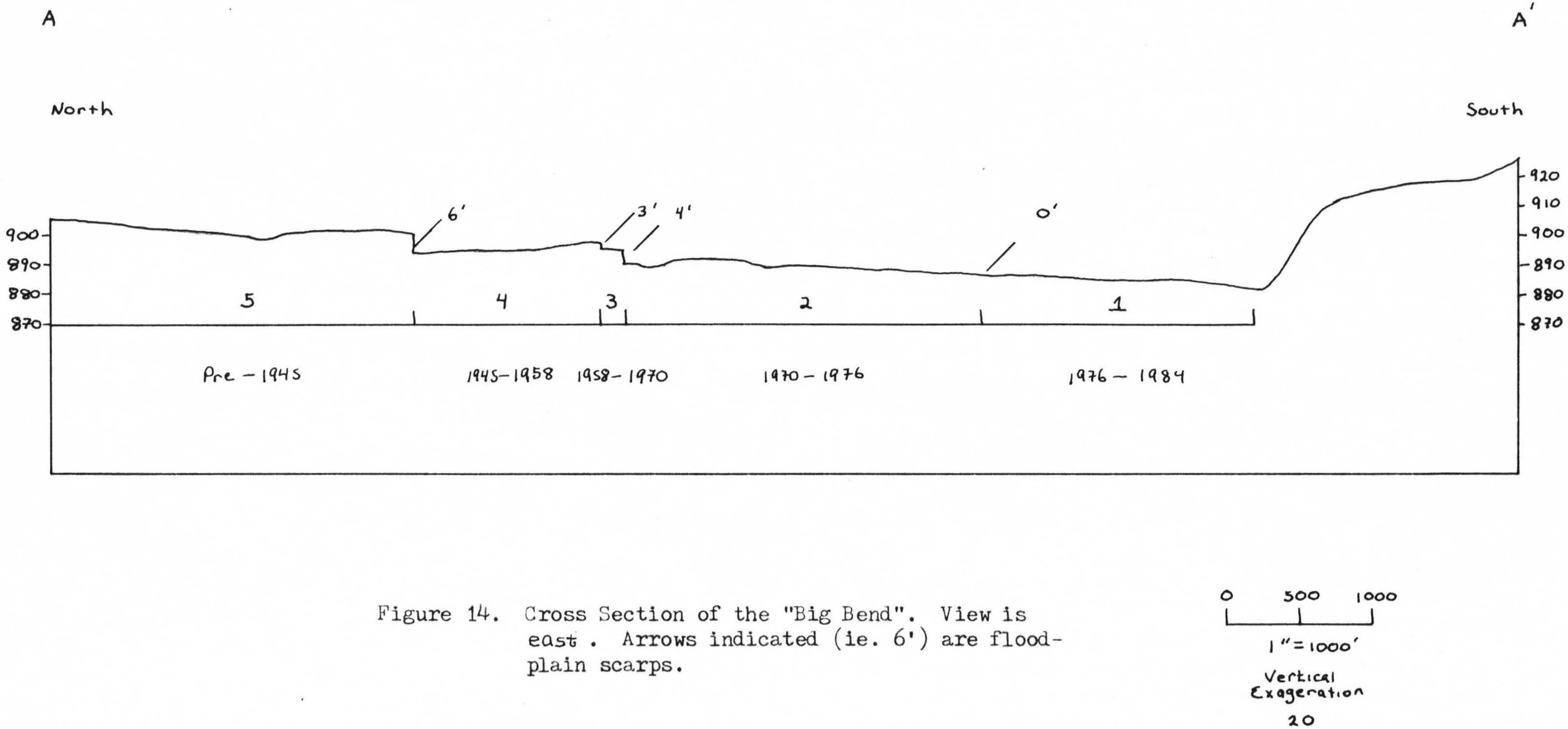


Figure 14. Cross Section of the "Big Bend". View is east . Arrows indicated (ie. 6') are flood-plain scarps.

Figure 15. Aerial photograph 7-14-40. Prior to mining, floodplain 5 is active and no apparent degradation is occurring. (Henderson Aerial Survey)

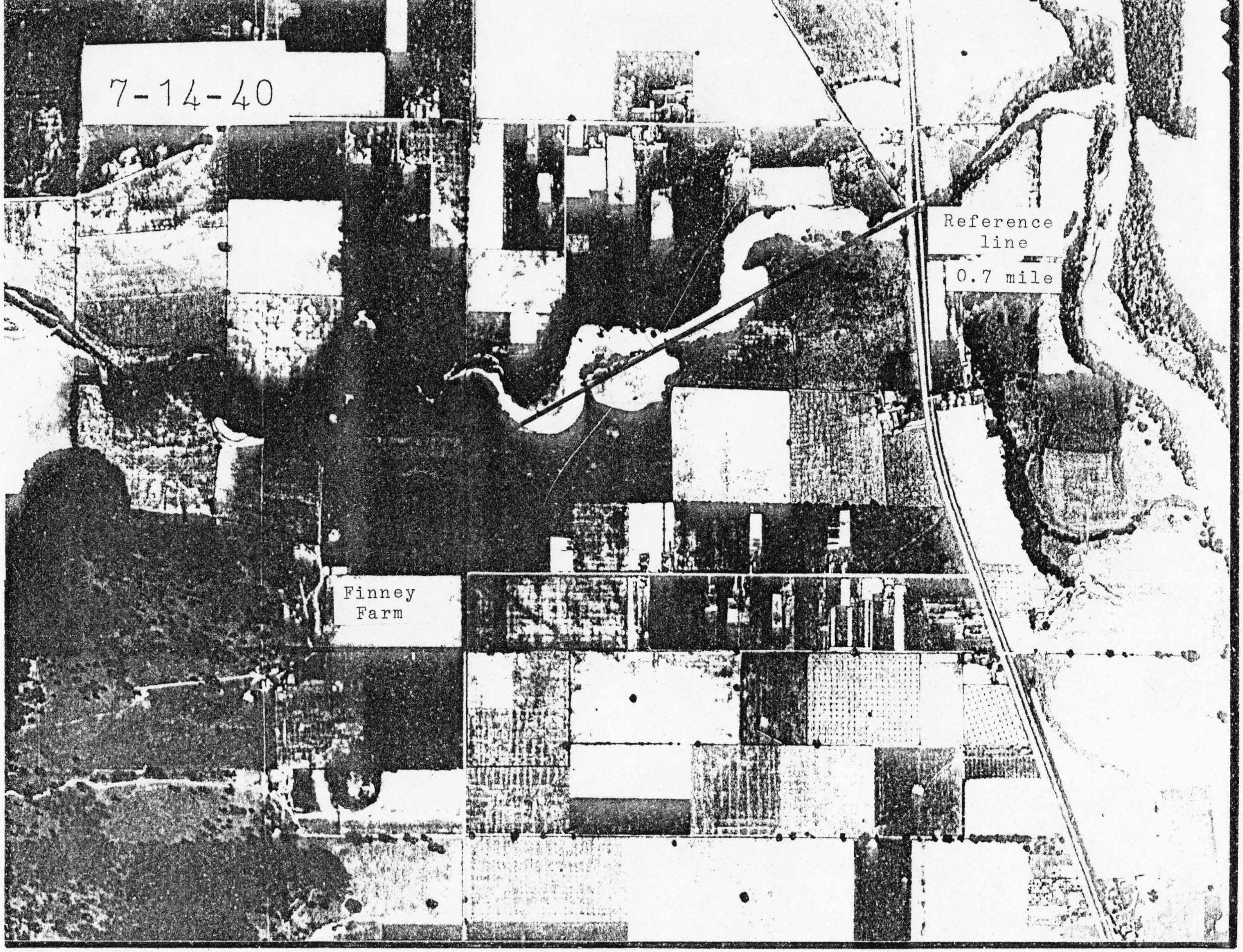
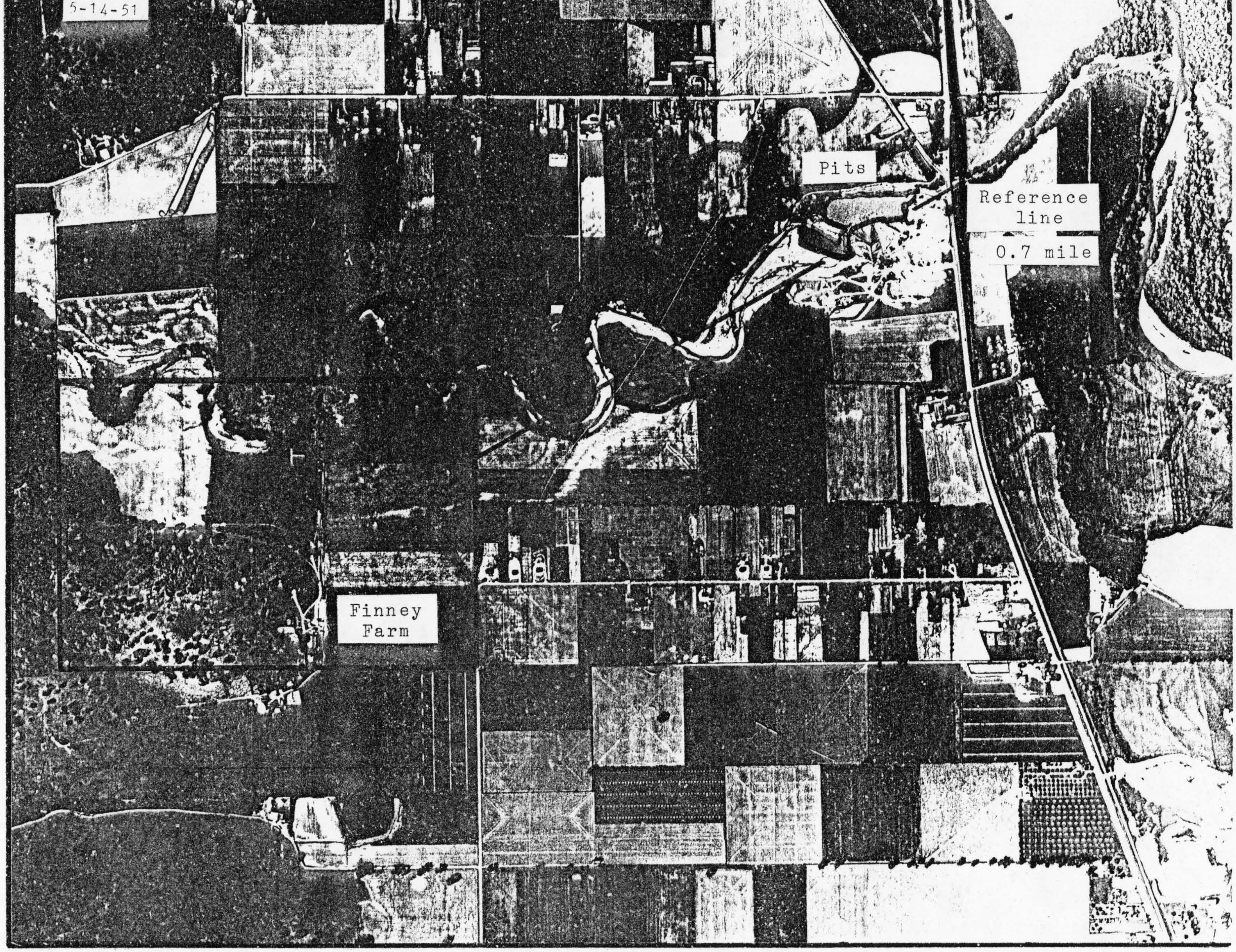

7-14-40
Reference line
0.7 mile
Finney Farm

Figure 16. Aerial Photograph 5-14-51. Degradation is seen progressing upstream after the start of mining. (Henderson Aerial Survey)



5-14-51
Pits
Reference line
0.7 mile
Finney Farm

Figure 17. Aerial Photograph 8-5-58. Degradation continues upstream as scarp 3 is being formed because of continued incision and lateral migration of the "Big Bend". (Henderson Aerial Survey)

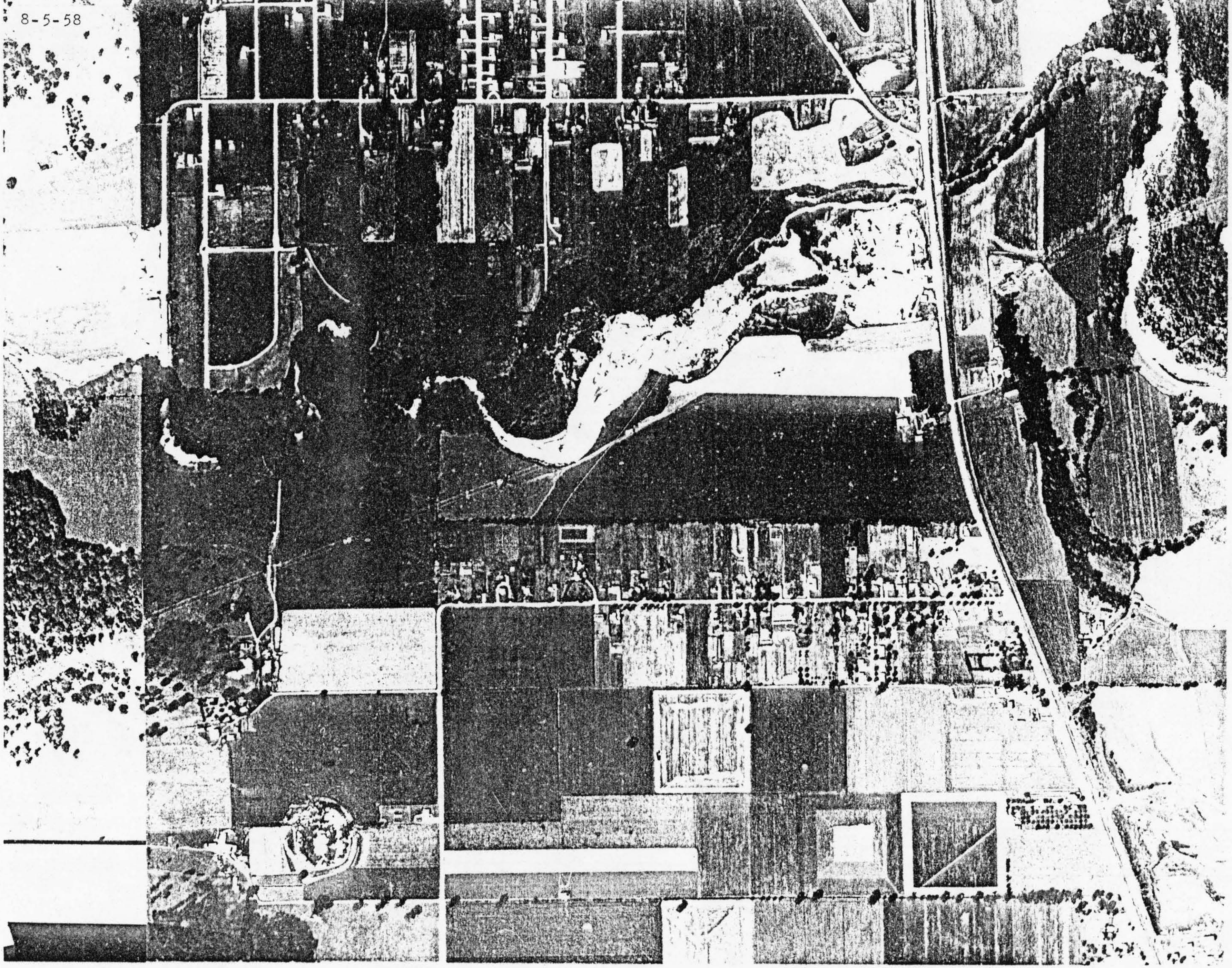

8-5-58

Figure 18. Aerial Photograph 4-24-62. Floodplain 3 is being eroded by the widening of the stream. (Henderson Aerial Survey)

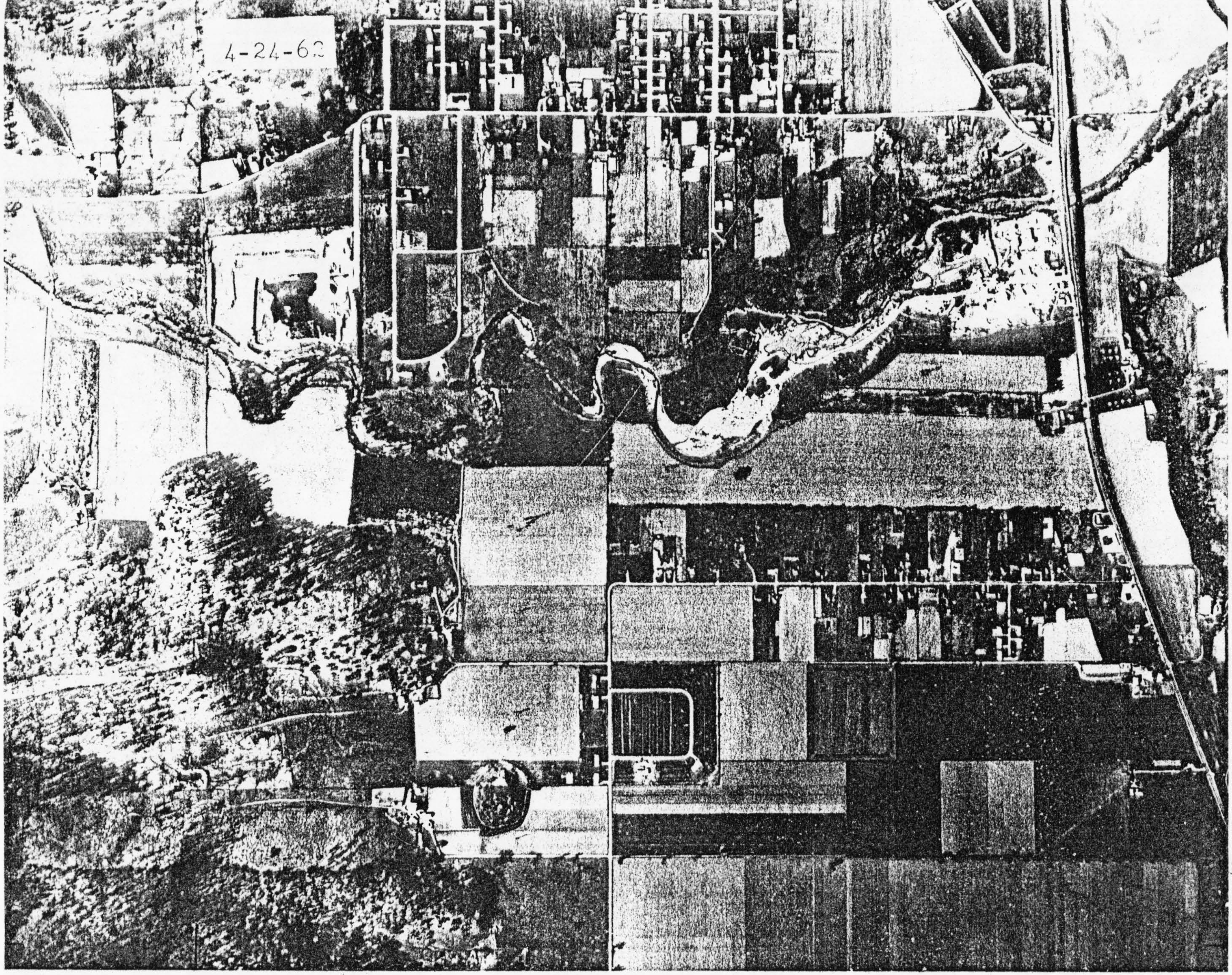

4-24-62

Figure 19. Aerial Photograph 6-17-64. The cutbank of the "Big Bend" is migrating due to the incision and meandering of the stream. (Henderson Aerial Survey)

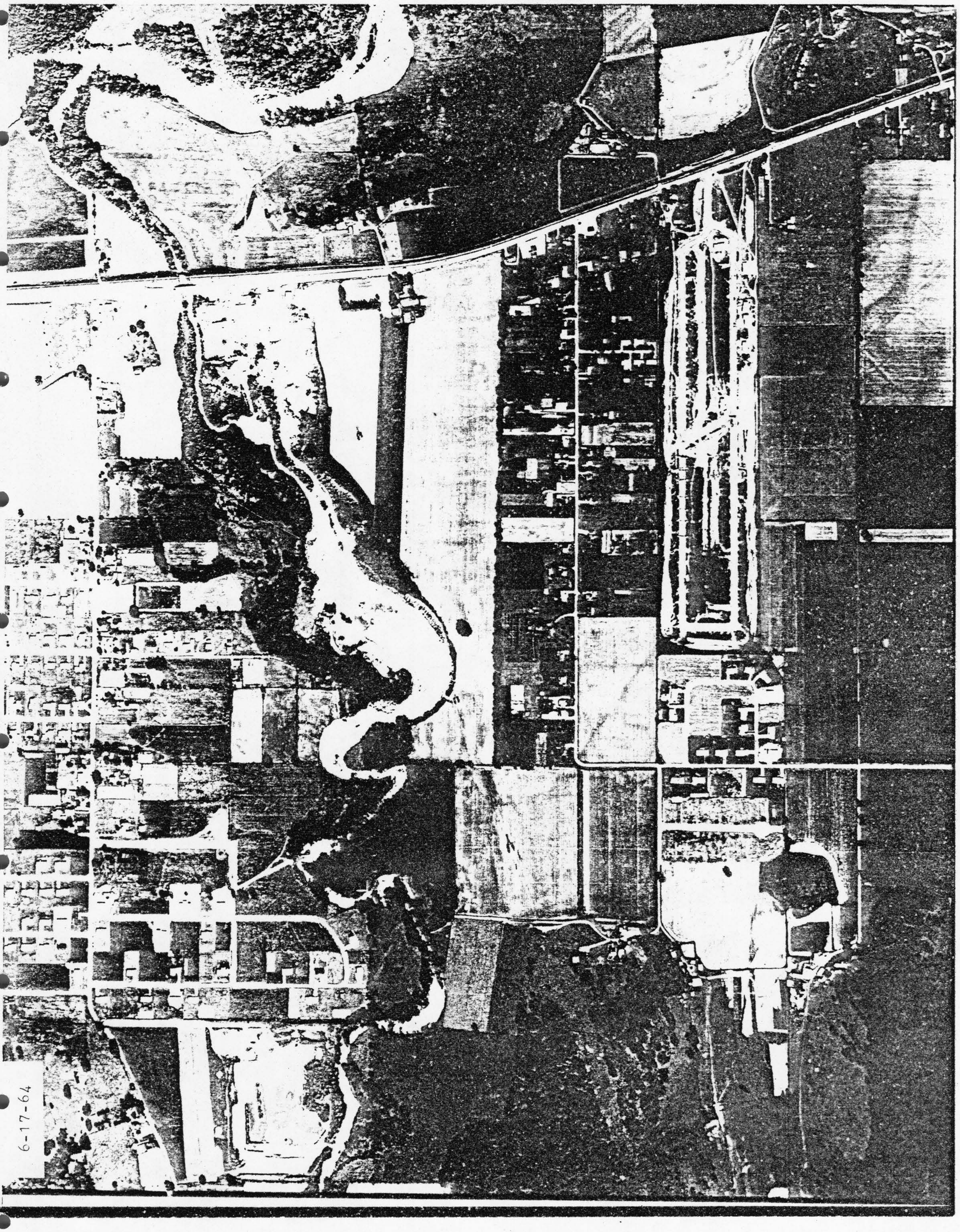

6-17-64

Figure 20. Aerial Photograph 5-26-70. Floodplain 3 is abandoned and floodplain 2 begins development. (Henderson Aerial Survey)

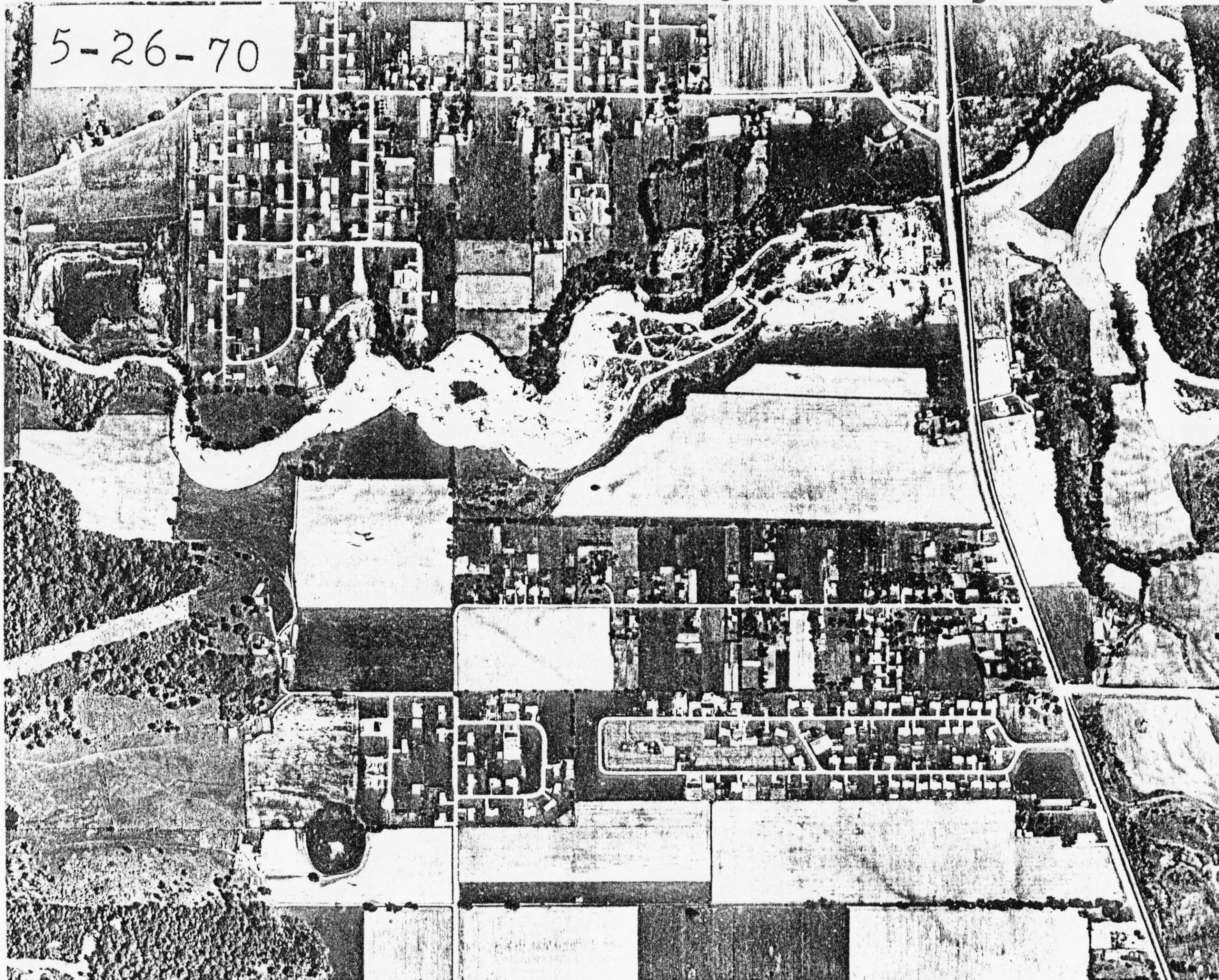
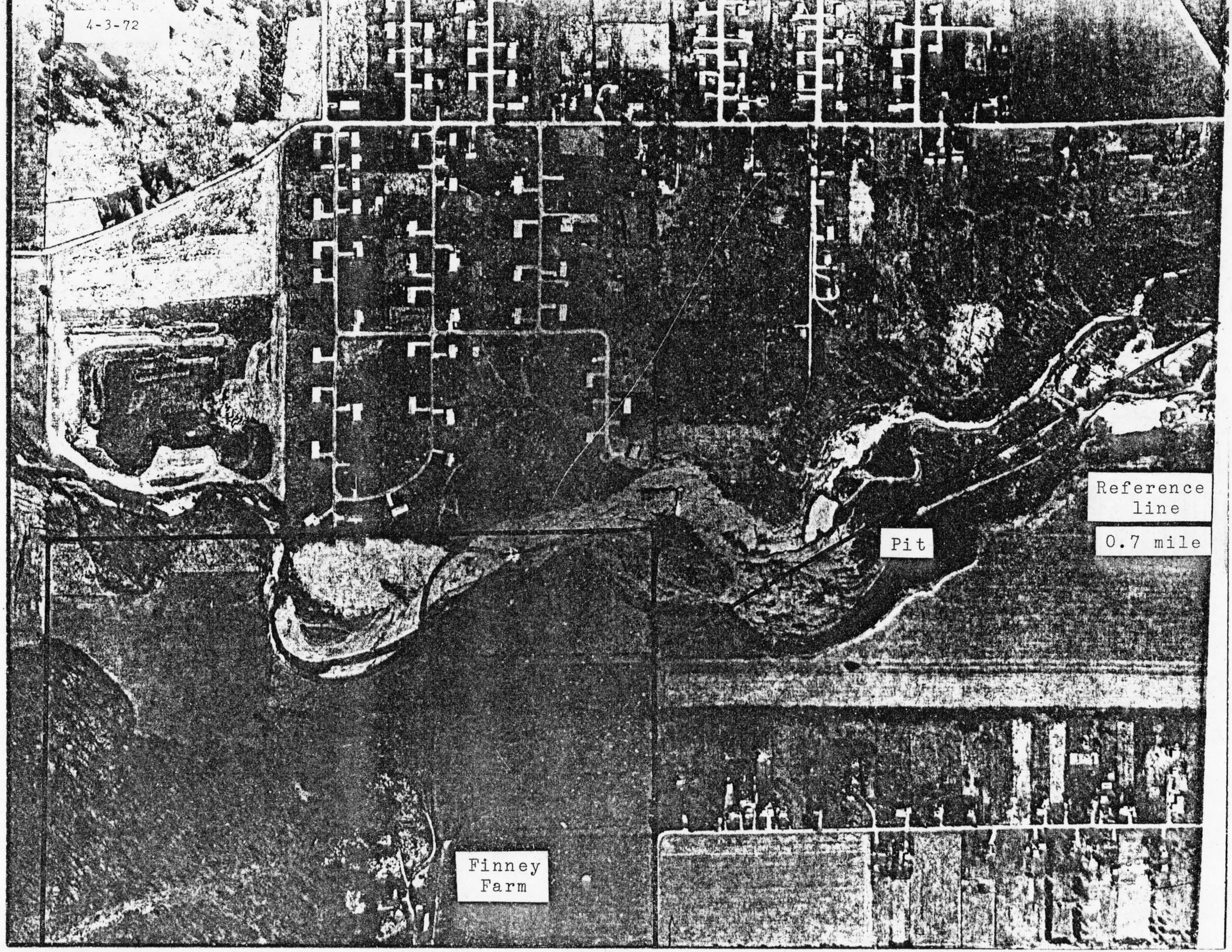

5-26-70

Figure 21. Aerial Photograph 4-3-72. Development of floodplain 2 continues. (Henderson Aerial Survey)



4-3-72
Reference line
0.7 mile
Pit
Finney Farm

Figure 22. Aerial Photograph 5-5-76. Floodplain 2 is abandoned as migration continues. (Henderson Aerial Survey)

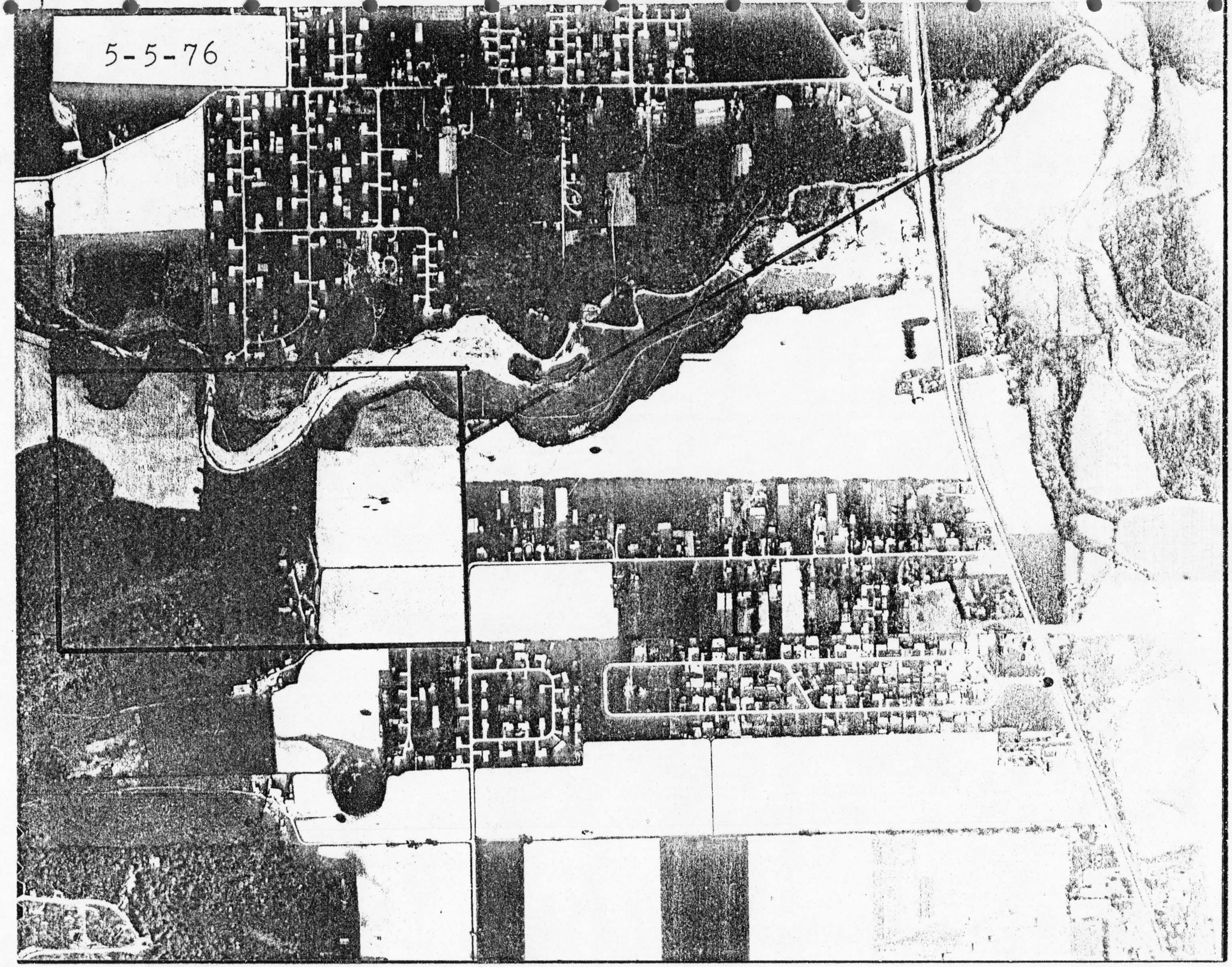

5-5-76

Figure 23. Aerial Photograph 3-13-83. This recent photograph shows the extent of lateral acreation of the point bar. Floodplain 1 is still active. (Henderson Aerial Survey)


3-13-83
UAg 51
152.31
WILD RC 8
AERIAL CAMERA
152.31 MM F.L.
HENDERSON
AERIAL
SURVEYS INC
5125 W. BROAD ST.
COLUMBUS,
OHIO 43228

Figure 24.

Floodplain Terraces on the "Big Bend" :

Their ages and gradients.

Floodplain	Age	Percent Grade
5	Pre -1945	2.00
4	1945 -1958	2.09
3	1958 -1970	2.15
2	1970 -1976	2.23
1	1976 -1984	2.28

Figure 24 displays the floodplains, their ages, and percent grade in tabular form showing the increase in the percent grade by nearly 0.3 since 1945. In the graphic representation (Figure 25) the increase is presented by definition, the fall or rise in feet for every 100 feet, and represents the progressive increase in slope for each terrace.

Because the average scarp height had been determined (Figure 14), and the age of the terraces were known (Figure 24), the average rate of downcutting was examined. The terrace scarp separating floodplain 5 and floodplain 4 (scarp 4) was developed between 1945 and 1958 while floodplain 4 was developing. Over these 13 years, the vertical extent of the scarp reached 6 feet indicating an average rate of downcutting of 5.5 inches per year. Scarp 3 developed 3 feet vertically from 1958 to 1970 indicating an average rate of downcutting of 3 inches per year. The rate of downcutting increased during

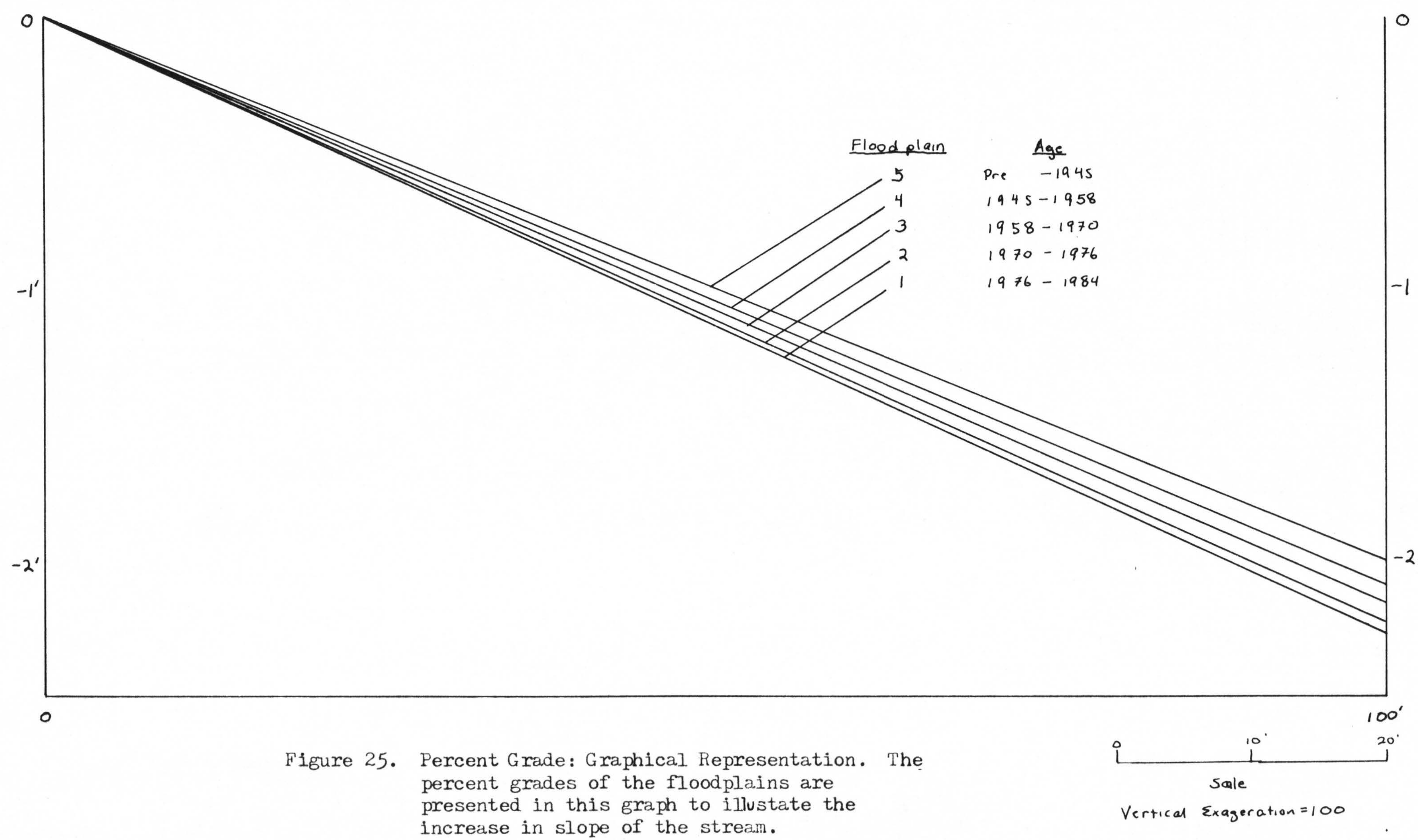


Figure 25. Percent Grade: Graphical Representation. The percent grades of the floodplains are presented in this graph to illustate the increase in slope of the stream.

development of scarp 2 to 8 inches per year between 1970 and 1976. Because floodplain 1 is still active and scarp 1 has little vertical extent, data collected from floodplains and scarps does not indicate a rate of downcutting. The above data does indicate, however, an average of 5 inches of downcutting per year from 1945 to 1976 (Figure 26).

A cross section showing progressive erosion of the "Big Bend" constructed by Finney (1983) indicates the level of the stream channel in 1962, 1976, and 1983, determined by aerial photographs and field measurements (Figure 27). This data indicates a rate of downcutting from 1976 to 1983 of 5.3 inches per year and a rate of downcutting from 1962 to 1983 of 4 inches per year. Compared to data collected from the floodplain terraces of 1958 to 1976 which indicates the average rate of downcutting to be 4.3 inches per year, the data collected by Finney is comparable.

The overall gradient of Dry Creek varies from the headwaters, where it is steep, to the lower reach, where it meanders with a gentle slope. The gentle slope increases near the study reach as it enters the mouth of the stream (Figure 28). Examination of other stream reaches that enter the North Fork of the Licking River does not indicate erosion of the type encountered at Dry Creek discounting it as a cause.

Climatic changes may dramatically affect the discharge which may increase or cause degradation. Daily and Monthly discharge of the Licking River near Newark, which is considered to be proportional to that of Dry Creek, indicates no dramatic change (Figure 29). A summary of precipitation also indicates no change (Figure 30).

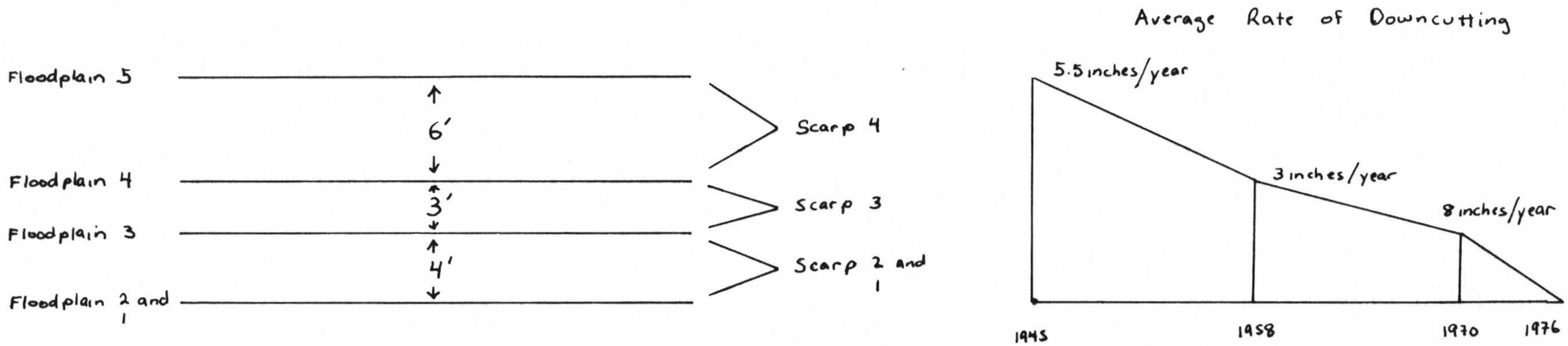


Figure 26. Floodplain terrace scarps and average rates of downcutting. Scarp heights are compared with the time span for which it took to attain the vertical extent. The average rate of downcutting from 1945 to 1976 is about 5 inches per year.

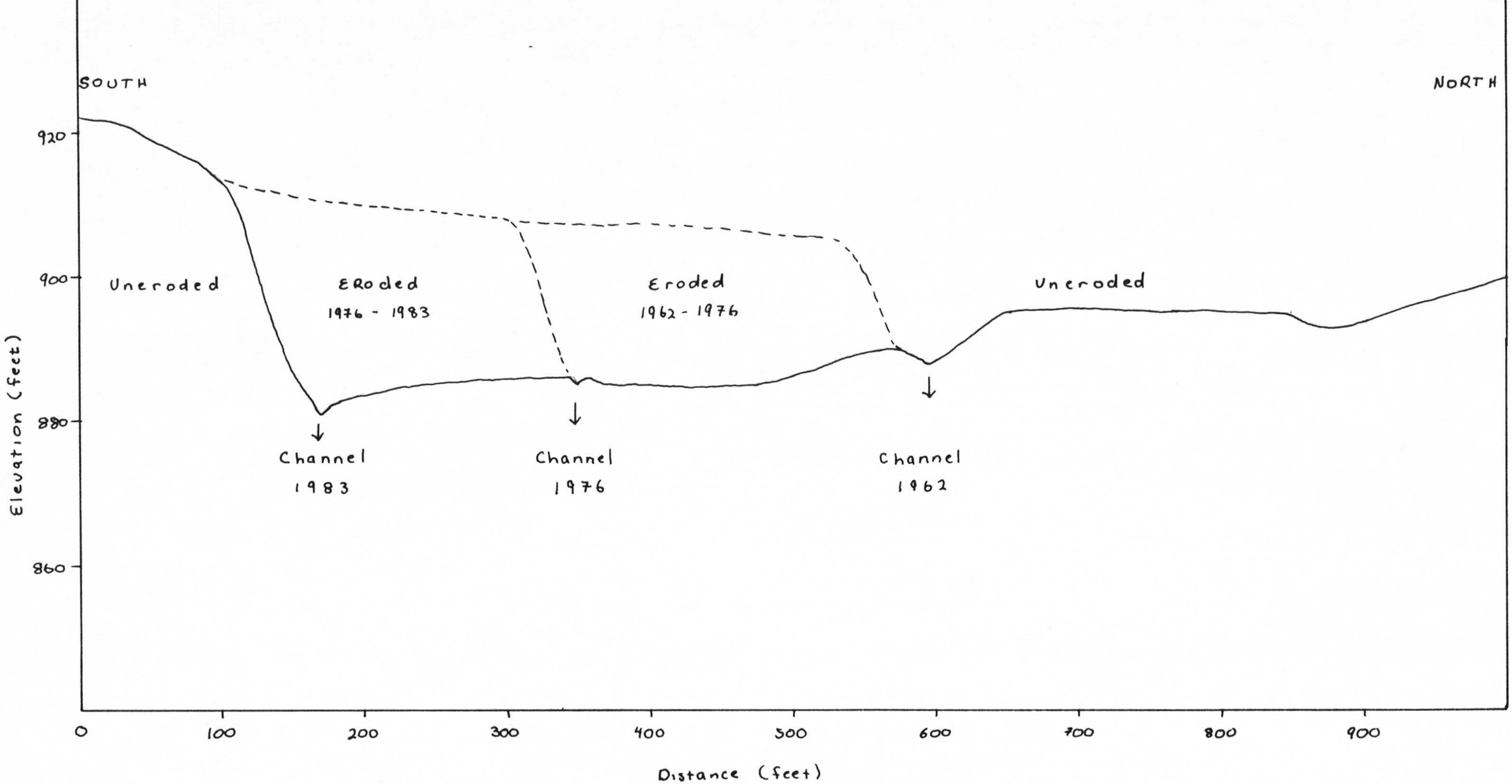


Figure 27. Ideal Cross Section of the "Big Bend" after Finney(1983). The cross section indicates the elevation of the stream channel at the year indicated. This data was taken from Figure 18, 22, and 23. It indicates an average rate of downcutting of 4 inches from 1962 to 1983, and 5.3 inches per year from 1976 to 1983.

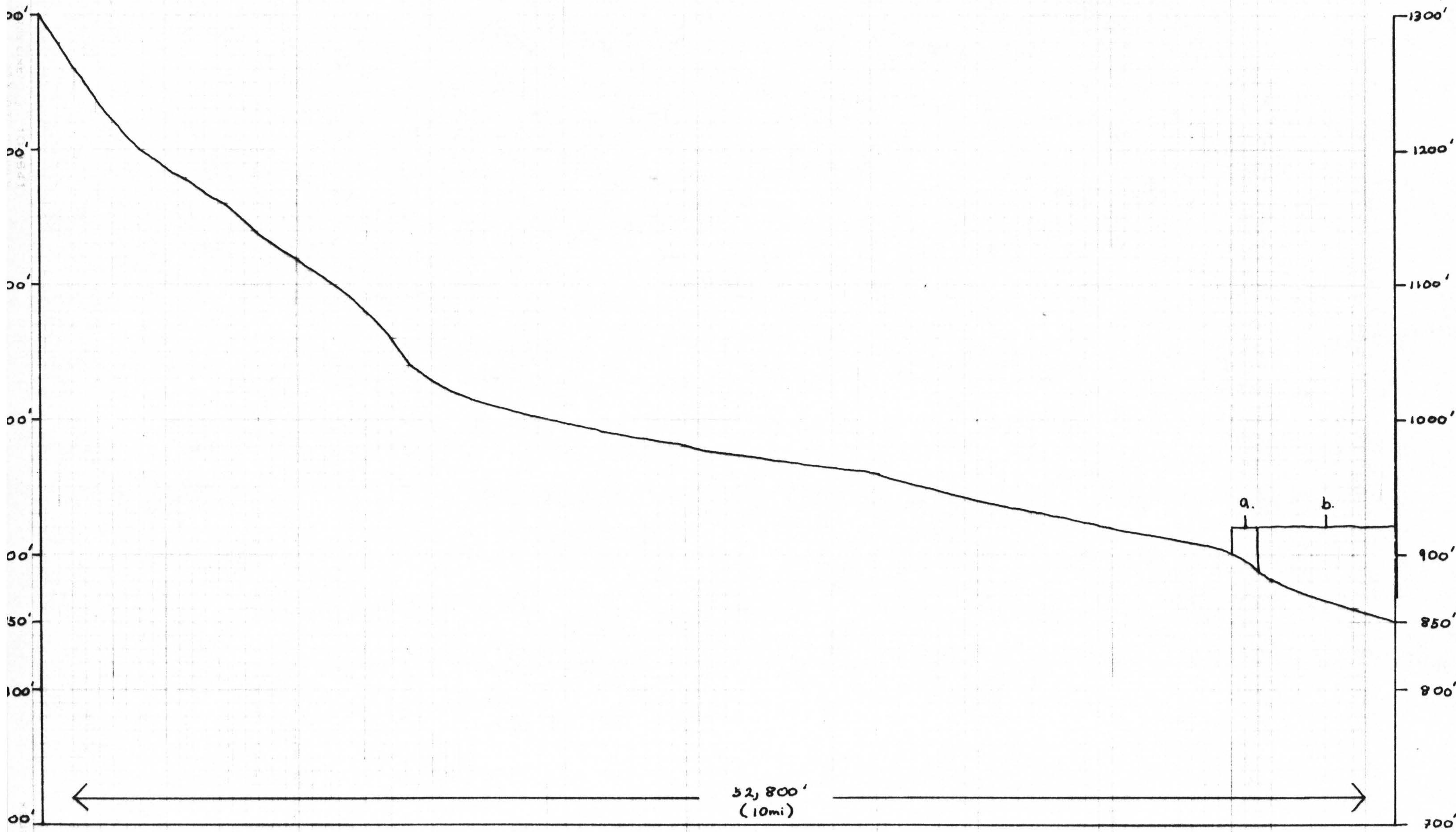


Figure 28. Slope of Dry Creek in 1910. This cross section taken from fifteen-minute topographic maps (Figure 2) is the ideal cross section of the stream. Segment a. is the "Big Bend" and segment b. is the rest of the stream into the North Fork of the Licking River.

Figure 29. Daily and monthly discharge of Licking River near Newark (Finney, 1983)

Water year (Oct-Sept)	Daily Month	Daily Am't.	Monthly Month	Monthly Am't.
1940	Apr.	16,500	Apr.	72,117
1941	Dec.	3,150	June	17,076
1942	Apr.	5,170	Feb.	30,452
1943	Mar.	13,000	Jan.	57,562
1944	Mar.	8,260	Mar.	46,877
1945	Mar.	15,000	Mar.	102,564
1946	Feb.	6,420	Mar.	41,277
1947	Jan.	7,280	May	56,760
1948	Feb.	11,700	Apr.	56,807
1949	Jan.	7,500	Jan.	65,744
1950	Jan.	10,800	Jan.	90,713
1951	Jan.	12,000	Jan.	58,638
1952	Jan.	20.300	Jan.	79,071
1953	July	2,810	Apr.	12,434
1954	Apr.	3,320	Apr.	17,040
1955	Mar.	5,940	Mar.	43,439
1956	June	8,590	Feb.	46,294
1957	Apr.	9,080	Apr.	49,285
1958	May	7.040	Dec.	42,538
1959	Jan.	25,600	Jan.	71,492
1960	Feb.	7,350	Feb.	35,626
1961	Apr.	8,470	Mar.	53,498
1962	Mar.	6,610	Mar.	45,269
1963	Mar.	21,100	Mar.	107,071
1964	Mar.	21,300	Mar.	75,925
1965	Apr.	5,300	Apr.	52,215
1966	Apr.	5,110	May	32,687
1967	Mar.	7,690	Mar.	63,577
1968	May	16,100	May	77,294
1969	June	10,000	Jan.	40,577
1970	Apr.	9,990	Apr.	63,286
1971	Feb.	4,790	Feb.	37,638
1972	Apr.	4,890	Apr.	46,229
1973	Nov.	5,750	Nov.	51,318
1974	Nov.	9,880	Jan.	44,482
1975	Feb.	14,800	Feb.	53,440
1976	Feb.	5,230	Feb.	38,442
1977	Apr.	5,630	Mar.	34,852
1978	Mar.	10,200	Mar.	64,781
1979	Sept.	15,200	Sept.	66,199
1980	Aug.	7,660	Mar.	47,286
1981	Apr.	9,190	Feb.	52,459

Figure 30. Newark Water Works, Newark, Ohio

Summary of Precipitation

Only Months with 6 Inches or More (Finney, 1983)

Year (19..)	Total (in.)	Month	Amount (in.)
35	38.9	8	8.1
36	36.1	None over 6 inches	
37	49.9	1	11.2[1]
		6	8.4
38	42.0	9	5.5
39	39.3	6	9.7[3]
40	43.4	4	7.1
44	35.3	3	6.8
45	44.4	3	9.1
47	41.5	5	6.7
48	43.2	4	6.1
50	48.0	1	9.7[3]
52	36.7	1	6.7
55	35.2	7	6.0
56	43.5	5	7.0
57	42.4	6	9.2
58	38.0	6	7.5
		7	7.4
59	43.1	1	6.7
		10	7.0
61	41.5	7	6.5
62	37.9	9	6.2
63	26.7	3	8.0
64	40.1	3	7.6
		4	7.3
		6	6.6
65	40.2	8	6.3
66	43.3	7	7.7
68	41.5	5	8.5
69	36.7	6	7.4
70	48.8	4	7.8
		5	6.0
		9	6.5
72	44.3	4	6.1
74	41.4	5	6.0
		8	6.4
76	37.1	6	6.4
77	44.8	7	6.0
78	48.1	1	6.0
		8	10.5[2]
79	53.7	7	9.4
		8	8.1
80	42.2	8	8.2
81	44.1	4	7.3
		5	6.0
		6	7.9

Discussion

Floodplain gradients determined in this study indicate a rapid increase of nearly 0.3 percent grade in this reach of the stream (Figure 24 and 25). The existence of well established floodplain terraces (Figure 14) illustrates the drastic changes that have occurred since 1945 and suggests a relative base-level change and/or changes in the discharge/sediment yield ratio in the basin (Richards, 1982). Figures 29 and 30 indicate no major changes in discharge other than a few peak years such as in 1945 and 1963. Otherwise there has been no significant climatic or discharge change that could have affected this basin, therefore this suggests that the relative base level has been altered.

The gradient of the whole stream (Figure 28) is, as expected, moderately steep at the headwaters were many first and second order streams enter and, expectedly, levels where the character of the stream changes from deep incision to gently meandering into the North Fork of the Licking River. As indicated on the cross-section, the slope significantly increases near the study reach suggesting a base level change prior to 1910 and mining. If degradation indicated in this study by increased gradients and production of terraces were caused by this change, then it would be expected to be evident in similar stream reaches along the North Fork. Rapid degradation is not evident along these tributaries suggesting a state of equilibrium or that upstream degradation is sufficiently slow not to be noticable in such a short period of time.

Noticable upstream degradation has occurred since the start of mining in 1945 on Dry Creek. Scour has rapidly moved upstream forcing the inhabitants to train the stream in order to protect their dwellings. The shortening of the stream length by 1444 feet (Stanley, 1984) increased flow velocities and peak discharges (Patrick,1982) resulting in erosion around the "Big Bend". This does not indicate causality, but does indicate another factor which has increased degradation of the channel reach.

Summary and Conclusions

Floodplain gradients have been documented to show an increase since 1945. Although the gradient of the stream before this time shows an increase, erosion or rapid degradation did not occur until commencement of excavation out of the streambed in the late 1940's, and similar streams show no reaction of this type. The production of terraces indicates a local base level change. Evidence presented in this study suggests that the base-level change has occurred through the lowering of the streambed. Progressing upstream degradation has been enhanced by the decrease in channel length.

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